NRL Participation in Model Error Analysis in the Framework of the MURI ASAP

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LONG-TERM GOALS

The long-term objective is to contribute to the development of the components of limited area, open boundary, and coastal nowcast/forecast systems that will resolve the time and length scales of the relevant physical-bio-optical dynamics in shallow coastal environments.

OBJECTIVES

In collaboration with Multi-disciplinary University Research Initiative (MURI) "Adaptive Sampling and Prediction (ASAP)" project scientists:
Evaluate the differences in NCOM, HOPS and ROMS predictions during AOSN II and MB2006 experiments.
Identify sources of three model differences and conduct error analysis of NCOM, HOPS and ROMS predictions.
Quantify and characterize the uncertainty in model forecasts based on the ensemble of one model or multi-model predictions.
Summarize lessons from the AOSN modeling efforts for future transition to the PLUS INP program.

APPROACH

Three circulation models were used during AOSN II (August of 2003) and MB2006 (August of 2006) experiments. These models are ROMS (Chao et. al, 2008), HOPS (Haley et al., 2008) and NCOM (Shulman et al., 2008). As demonstrated in three models' summary table at https://aosn.mbari.org/coop/, these models, while all being hydrostatic, primitive equations models, have had significant differences in resolution, nesting, initialization, data assimilation schemes, mixing parameterization etc. At the same time, all three models were forced with the same atmospheric forcing (Doyle et al., 2008) and the observations assimilated into the models were almost the same. In some instances, the predictions from the three models were significantly different, as was demonstrated during five virtual pilot experiments (VPE, when model predictions during AOSN II were used), as well as during the real-time MB2006 experiment. There is a need to identify the main reasons for three model simulations being so different, and based on this, to quantify the uncertainty of the environmental conditions in model predictions. In collaboration with the ASAP group, our approach is based on conducting numerical experiments to help in identifying the error sources and differences in model predictions. These experiments use the same initial conditions, and comparisons are done during strong/weak remote forcing events, as well as strong/weak atmospheric events (upwelling/relaxation).

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14. ABSTRACT
The long-term objective is to contribute to the development of the components of limited area, open boundary, and coastal nowcast/forecast systems that will resolve the time and length scales of the relevant physical-bio-optical dynamics in shallow coastal environments.

15. SUBJECT TERMS

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WORK COMPLETED

We attended the MURI ASAP meeting (June 10-12 of 2008). In collaboration with MURI ASAP PIs, we developed the plan for models comparisons and future research directions.

We conducted numerical experiments when the NCOM model initial and open boundary conditions were derived from the HOPS model forecast. The experiments were conducted during strong/weak wind events (upwelling/relaxation). The NCOM model was run for two days, and because the HOPS forecast was used for initial and open boundary conditions, no observations were assimilated. The NCOM and HOPS forecasts were compared and differences were analyzed.

In collaboration with Dr. Fumin Zhang of Georgia Tech, the estimations of the three models' prediction errors based on the projected and observed glider trajectories were calculated. Also, with Dr. Steve Ramp, we participated in the three models' predictions comparisons at ADCP1 and ADCP2 located to the north of the Bay. We have provided the NCOM model outputs to the Caltech group for comparisons of the LCS structures derived from the three models.

We have completed the revision of the four papers for the AOSN II special issues, and all four papers were accepted.

RESULTS

Figure 1 shows the differences in surface currents, SST and surface salinity between NCOM and HOPS forecasts during the upwelling event of August 9-11 of 2006. The NCOM model was initialized from the HOPS forecast on August 9th 3Z. The NCOM model was forced with COMAPS 3km (same forcing as in HOPS forecast) and run for 2 days, and the open boundary conditions were derived from the HOPS forecast. Because comparisons are made with the HOPS forecast, (used as initial and open boundary conditions) no observations were assimilated. The differences between NCOM and HOPS are averaged over 45 hours (Figure 1). In spite of the fact that NCOM started from the HOPS forecast and used HOPS values on open boundaries, the averages of NCOM and HOPS forecasts show significant differences over 45 hours of forecast. The NCOM model shows stronger onshore (Figure 1, a) and alongshore (Figure 1, b) components of currents along the upwelling centers at Ano Nuevo (north) and Pt. Sur (south). Because the same wind is used as surface boundary conditions in both models, the differences in surface currents might be attributed to the differences in horizontal and vertical momentum mixing schemes used in the models: Smagorinsky formula for horizontal mixing and Mellor-Yamada 2.5 scheme for vertical mixing in the NCOM, and scale-selective Shapiro filter for horizontal numerical diffusion and Laplacian mixing in vertical for HOPS (see three models summary table at https://aosn.mbari.org/coop/). As a result, the NCOM model forecast has colder and more saline water masses then HOPS forecast around the upwelling centers and in filaments advected away from the upwelling centers (Figure 1 c and d). However, in spite of the stronger upwelling in the NCOM forecast (which should result in advection of the colder and more saline upwelled water into

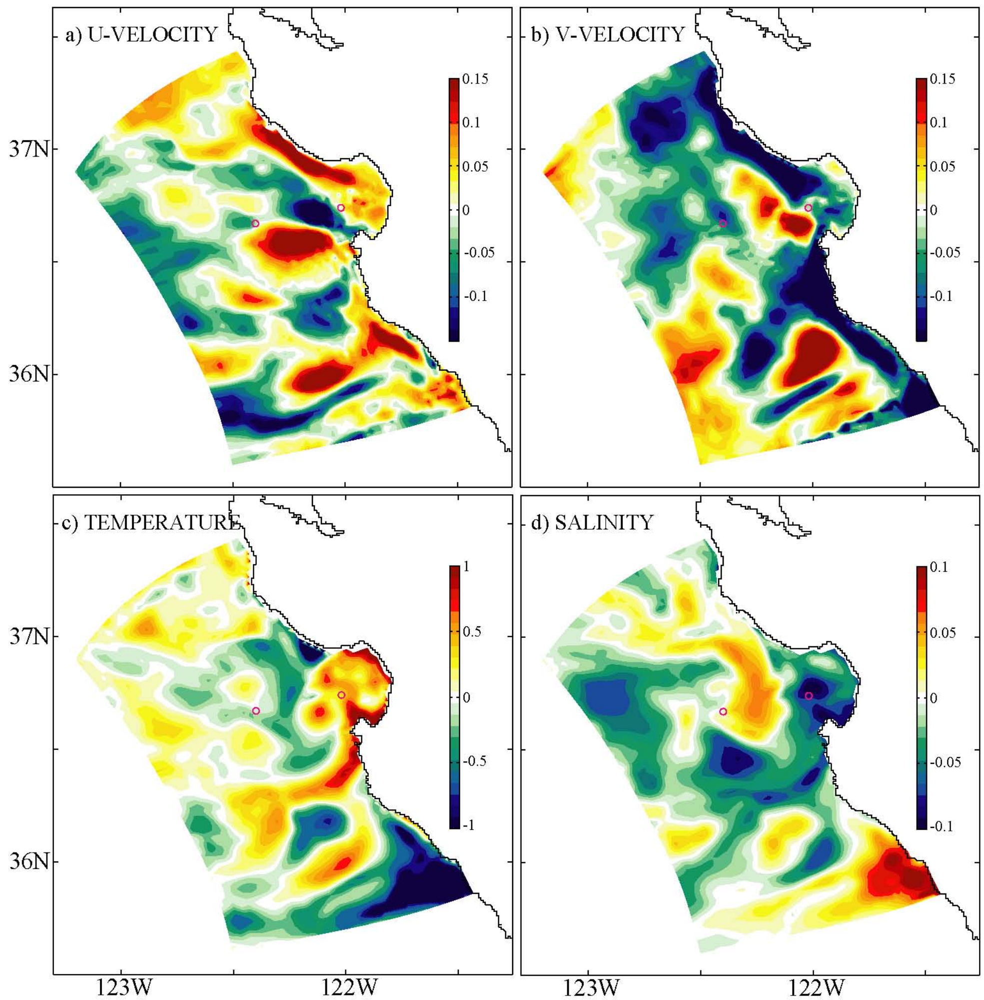

Figure 1. The differences between velocities, temperatures and salinities of the NCOM and HOPS forecasts at surface. The differences are averaged over 45 hours [Figure shows that the upwelling is stronger in the NCOM model forecast than in the HOPS forecast].

the Bay), the NCOM model has much warmer and less saline water masses in the bay than the HOPS forecast (Figure 1). More research to explain this should be conducted, but one of the reasons for this is the difference in horizontal and vertical mixing schemes for heat and salt in the models. As it was stated above, the NCOM model open boundary values are derived from the HOPS forecast and it is reasonable to expect that two model forecasts will be similar as we approach the open boundaries. However, based on Figure 1, this is not the case. For example, stronger upwelling in the NCOM solution resulted in development of the plume of the colder and more saline water along the southern open boundary.

Pierre Lermusiaux of MIT conducted similar experiments by initializing HOPS with the NCOM model outputs, and he concluded that the use of the same initial conditions provide similar forecasts from two models (presentation at ONR MURI ASAP Review, May 2007). He compared temperature and salinity HOPS and NCOM fields at 100m. Figure 2 shows the differences between the NCOM and HOPS forecasts at 100m from our described above experiment. The differences between the two forecasts are

smaller than at the surface (Figure 1), especially for temperature and salinity. However, there are prominent differences in currents reaching a magnitude of 15cm/s at 100m depth.

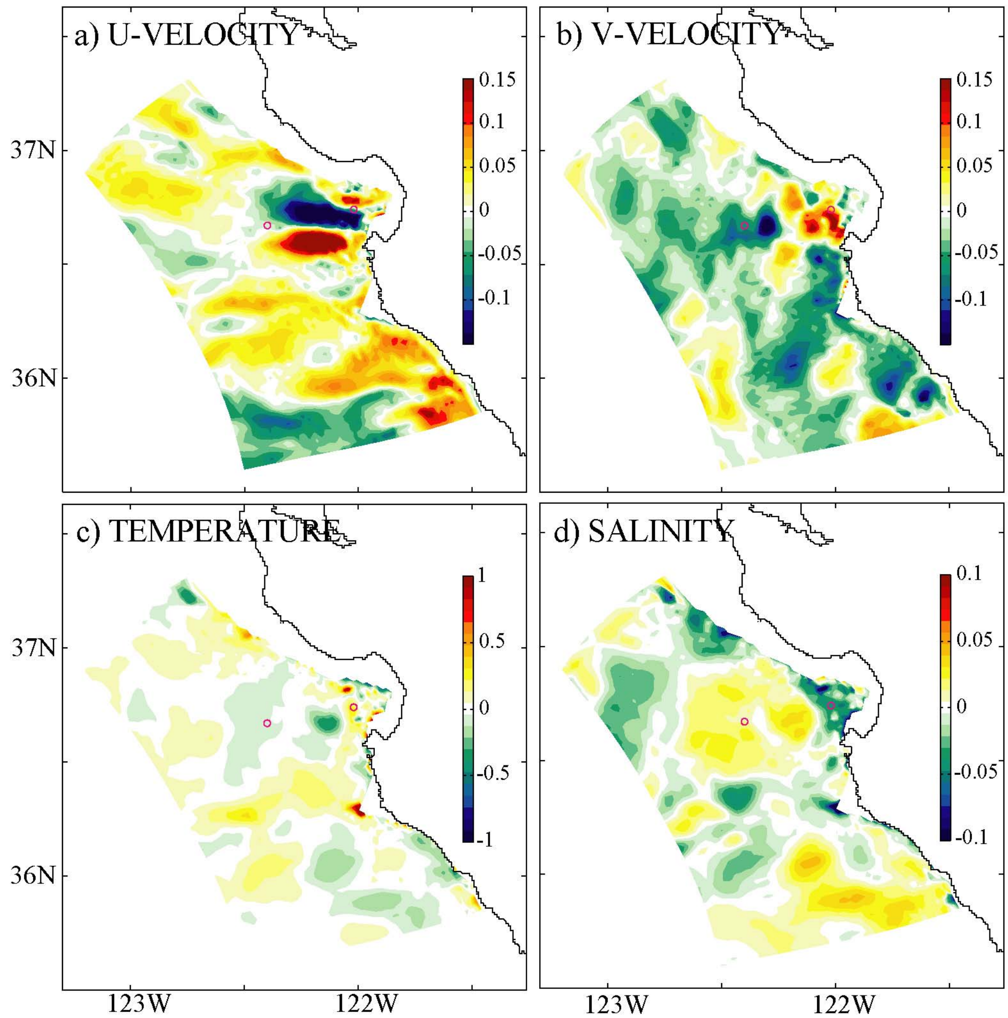

Figure 2. The differences between velocities, temperatures and salinities of the NCOM and HOPS forecasts at 100m depth. The differences are averaged over 45 hours. [Figure shows that the differences in NCOM and HOPS currents are reaching a magnitude of 15cm/s at 100m depth].

IMPACT/APPLICATIONS

In situations where it is difficult to obtain extensive data sets to validate numerical models and techniques in areas of Navy strategic importance, our development and testing of the components of limited area, open boundary, coastal nowcast/forecast systems, together with extensive observational programs in and around the Monterey Bay Area, allow continued development of novel techniques for data assimilation and adaptive sampling.

TRANSITIONS

Model predictions were provided to the Collaborative Ocean Observatory Portal of the MB2006 experiment.

RELATED PROJECTS

DOD/ONR MURI ASAP (PIs: N. Leonard and S. Ramp)
Coordination with a joint effort by the Princeton, NPS, Harvard, MIT, MBARI, WHOI, NPS, etc. in MB2006 post-experiment analysis.

NRL Bio-Optical Studies of Predictability and Assimilation for the Coastal Environment (BIOSPACE) (PI: I. Shulman)
I. Shulman is actively involved in coupled bio-optical physical modeling and data assimilation in the framework of this project.

NRL, "Variational Data assimilation for Ocean Prediction" (PI: H. Ngodock, Co-PI: I. Shulman)
Development of advanced variational data assimilation techniques.

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